Table 1 *Biomass and ionic composition of Azolla pinnata cultured in nitrogen-free medium supplemented with various levels of sodium chloride*

NaCl level (mM)	Fresh weight (mg)	Dry weight (mg)	Sodium (mg/g dry wt)	Chloride (mg/g dry wt)	Calcium (mg/g dry wt)	Potassium (mg/g dry wt)	Magnesium (mg/g dry wt)
Control (NaCl absent)	2590	103	4.3	7.9	8.9	29.8	4.9
5	2570	102	4.9	8.6	8.6	29.3	4.9
10	2530	101	5.1	9.1	8.5	29.0	4.9
20	1760	72	5.6	10.7	7.3	26.1	4.9
30	1080	39	6.3	15.3	6.1	19.8	4.7
40	720	29	7.6	19.8	5.3	11.4	4.5
50	—	—	—	—	—	—	—
CD at 5%	134	7.3	—	—	—	—	—

medium containing up to 40 mM sodium chloride indicating that this level is tolerable, but further increase did not allow growth.

One of the authors (KR) is thankful to UGC, New Delhi, for a fellowship.

17 August 1988; Revised 27 December 1988

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BIOCHEMICAL CHANGES IN TUKRA-AFFECTED EXOTIC MULBERRY PLANTS

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MEALYBUGS causing tukra disease[1] in mulberry were reported by Roy[2] and Paul[3] in 1941. The bugs feed on the tender leaves and shoots of mulberry. The affected plants show curling of leaves at the growing point and arrested growth. The disease is caused by a virus transmitted by the common mealybug, viz. *Maconellicoccus hirsutus*[4,5]. Rearing young-age silkworms is solely dependent on the tender leaves of mulberry.

In tukra the leaves are very badly damaged. Not only do the leaves show morphological changes (deformed, crinkled, wrinkled, etc.), but biochemically also they differ[6,7] from normal leaves. This affects the nutritional status of the leaves. During a survey, between August 1985 and February 1986, of mulberry plants in the germplasm bank in the Bangalore University campus, *Morus australis*, *M. cathyana*, *M. macroura* and *M. nigra* were reported to be free from tukra attack[8]. However, in May–June 1988, these plants were also severely affected in the same garden as all the other varieties were also attacked by the mealybugs. Biochemical changes in leaves of the four exotic species mentioned above were investigated.

Tukra-affected and unaffected leaf samples of *M. australis* Pair. (Australia, Indonesia, Philippines, South China), *M. cathyana* Hemsl. (Central China), *M. macroura* Mig. (China, Indonesia, Japan) and *M. nigra* L. (Persia, West Asia) were collected during May–June 1988 and oven-dried. The samples were analysed for total chlorophyll[9], protein[10], sugars[11], reducing sugars[12], phenols[13] and starch[14].

The data are given in table 1. There was a decrease in protein content of *Morus macroura* and *M. nigra* affected by tukra; the reduction was, however, negligible in *M. nigra*. Tukra caused an increase in protein content of the other two species, viz. *M. australis* and *M. cathyana*. In an earlier study[7] protein content decreased by 10.5% in mulberry variety Kajali while in variety Kanva-2 it increased significantly (40%). Increase in protein content may be due to induced synthesis of protein in response to the infection[15], while reduction in protein content may be attributed to hydrolysis by proteolytic enzymes secreted by the pathogen[16].

Morus macroura and *M. nigra* affected by tukra showed a decrease in the level of phenols. On the

Table 1 *Biochemical changes in tukra-affected exotic mulberry species*

Species		Protein	Phenols	Starch	Reducing sugars	Sugars
			(all mg/g dry wt)			
Morus australis	Uninfected (UI)	142.50	90.00	109 80	48.00	132.00
	Infected (I)	162.00	118.00	106.20	49.50	128.00
	Change (%)	+13.68	+31.11	−3.27	+3 12	−3.30
M. cathyana	UI	115.40	95 00	99.00	42.00	120.00
	I	126.00	115.00	97.20	37.60	118.00
	%	+9.18	+21.05	−1.80	−10 47	−1.66
M. macroura	UI	136.85	128 00	73.80	44 00	92.00
	I	128.50	110.00	93.15	51.50	113.50
	%	−6.10	−14.06	+26.21	+17.04	+23.36
M nigra	UI	130.50	125.00	113.20	30 00	158 00
	I	127.60	115.00	127.08	28.00	151.20
	%	−2.22	−8.00	+12.28	−6.66	−4 30

Each value is mean of six samples.

contrary, there was a significant increase in *M. australis* and *M. cathyana*. Such increase or decrease in phenolic content has been noticed in a number of other host–pathogen combinations[17,18]. Interaction between the pathogen and the host might have triggered production of more phenols. Decrease in phenolics may be a result of severe infection[19].

Starch content was, however, increased in tukra-affected *M. macroura* and *M. nigra*. The increase was significant in *M. macroura*. There was only negligible decrease in *M. australis* and *M. cathyana*. In the earlier study[7] Kajali and Kanva-2 showed an increase in starch content. Alabi and Nagvi[20] suggested that starch is not normally utilized for growth by the pathogen, hence it accumulates in the leaf tissue. Reduction in the starch content of affected leaves may be due to enzymatic activity of the pathogen, as evidenced by the increased reducing sugar content of infected parts[21].

Sugar content of tukra-affected *M. australis*, *M. cathyana* and *M. nigra* was marginally decreased. However, tukra caused significant increase in sugar and reducing sugar level of *M. macroura*. An increase in reducing sugar was noticed in tukra-affected *M. australis* also, but it was negligible. In *M. cathyana* and *M. nigra*, tukra brought down the level of reducing sugars. The two indigenous mulberry varieties, Kajali and Kanva-2, also showed an increase in sugar content when affected by tukra[7]. It also appears that the infection induces production of soluble sugars, which may be metabolized by the pathogen for its growth[22]. Decrease in reducing sugars may be due to the reduction in leaf lamina and malformation of leaves in tukra-affected plants. A close study of the changes in reducing sugars and phenols in infected plants showed that phenols accumulated at the expense of reducing sugars in all the species except *M. macroura*. This is in conformity with the work of Rama Pandu and Raychoudhuri[23]. However, the overall decrease in reducing sugars could be due to the utilization of the sugars by the pathogen for its multiplication. Increase in reducing sugar content after infection may be due to disturbed host metabolism and marked stimulation of CO_2 fixation in the affected leaves[24].

Total chlorophyll, chlorophyll *a* and *b* and chlorophyll *a/b* ratio in healthy and tukra-affected plants are given in table 2. There was significant reduction in total chlorophyll, chlorophyll *a* and *b* and chlorophyll *a/b* ratio in tukra-affected *Morus cathyana*. Although *M. australis*, *m. macroura* and *M. nigra* recorded an increase in total chlorophyll and chlorophyll *a* and *b*, the *a/b* ratio was decreased. Increase in total chlorophyll and chlorophyll *a* and *b* was significant in *M. nigra*, marginal in *M. macroura* and slightly more in *M. australis*. Except chlorophyll *b* in variety Kajali, all these quantities were increased as a result of tukra attack in both Kanva-2 and Kajali varieties[7].

Diseased tissue usually contains considerably less chlorophyll than healthy leaves. It is interesting that chlorophyll content, particularly chlorophyll *b*, was higher in tukra-affected plants, except *M. cathyana*.

Increase in chlorophyll content of tukra-affected leaves may be due to failure of the pathogen to inhibit chlorophyllase enzymes, as in okra[24]. Roberts and Corbett[25] reported reduced photosynthesis in

Table 2 *Changes in chlorophyll content of tukra-affected exotic mulberry species*

Species		Chlorophyll (mg/g dry wt)			
		Total	Chl *a*	Chl *b*	*a/b* Ratio
Morus australis	Uninfected (UI)	4.82	2.60	2.25	1.155
	Infected (I)	5.14	2.72	2.42	1.127
	Change (%)	+6.63	+4.61	+7.55	−2.424
M. cathyana	UI	3.91	2.05	1.86	1.102
	I	3.03	1.45	1.58	0.917
	%	−22.50	−29.26	−15.05	−16.787
M. macroura	UI	5.28	2.72	2.56	1.062
	I	5.52	2.84	2.68	1.059
	%	+4.54	+4.41	+4.68	−0.282
M. nigra	UI	4.50	2.48	2.02	1.227
	I	5.20	2.85	2.35	1.212
	%	+15.55	+14.91	+16.33	−1.220

Each value is mean of six samples.

tobacco plants and demonstrated that a symptomless tissue of low virus content showed reduced photosynthesis per unit of chlorophyll, suggesting that perturbation of photosynthesis did not result from chlorophyll loss; on the contrary, the tissue had slightly increased chlorophyll content per unit leaf area and appeared greener than uninfected tissue. Similar results were obtained in Kanva-2 variety of mulberry in powdery mildew and virus infections[26].

23 September 1988; Revised 31 January 1989

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